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2.	Patent application number *(The Patent Office will fill in this part)*	0314229.6 — 19 JUN 2003
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Meighs Limited Campbell Road Stoke-On-Trent Staffordshire ST4 4ER
	Patents ADP number *(if you know it)*	8655433001
	If the applicant is a corporate body, give the country/state of its incorporation	England
4.	Title of the invention	Alloys
5.	Name of your agent *(if you have one)*	Barker Brettell
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	138 Hagley Road Edgbaston Birmingham B16 9PW
	Patents ADP number *(if you know it)*	7442494002

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11.		I/We request the grant of a patent on the basis of this application. Signature Barker Brettell Date **Barker Brettell** 18 June 2003
12.	Name and daytime telephone number of person to contact in the United Kingdom	David A. Wightman Tel: 0121 456 1364

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DUPLICATE

ALLOYS

This invention relates to alloys and in particular to copper-nickel-manganese-aluminium alloys (hereinafter Cu-Ni-Mn-Al alloys).

Cu-Ni-Mn-Al alloys are widely used in marine environments where resistance to corrosion and hydrogen embrittlement are highly desirable.

For applications where high strength and wear are especially desirable, for example bearings, beryllium-copper alloys are currently preferred to Cu-Ni-Mn-Al alloys. However, beryllium is highly toxic and a Cu-Ni-Mn-Al alloy having comparable properties to existing beryllium-copper alloys would be highly desirable.

The present invention seeks to provide a Cu-Ni-Mn-Al alloy having improved properties capable of wider application.

It is a desired object of the present invention to provide a Cu-Ni-Mn-Al alloy that can be used for bearing applications where high strength and high hardness which result in resistance to wear are especially desirable.

The above aims and objections are broadly achieved by the provision of a Cu-Ni-Mn-Al alloy containing nickel in the range $\geq$ 19% to $\leq$ 26% by weight, aluminium in the range $\geq$ 1.9% to $\leq$ 3.2% by weight and which possesses a Ni:Al ratio of between 6.5 and 10 (in terms of wt%).

Cu-Ni-Mn-Al alloys according to the present invention are suitable for use in bearing applications and can be provided in place of existing beryllium-copper alloys which pose health and safety risks due to the toxicity of beryllium.

Preferably Cu-Ni-Mn-Al alloys according to the invention include iron, chromium and niobium and optionally include one or more of titanium, vanadium, silicon, tantalum or tungsten.

The strength of the invented Cu-Ni-Mn-Al alloys is understood to derive from the precipitation of nanometre-scale Ni_3Al (γ') phases. By employing a Ni:Al ratio of 6.5:10 (in terms of wt%), the formation Ni_3Al can proceed to completion leaving a proportion of nickel in solution in the copper matrix to effect solid solution hardening.

Crystallographic measurements of the lattice parameters of Ni_3Al with the addition of various elements show that elements such as silicon and vanadium decrease the lattice constant and the elements iron, chromium, manganese, titanium, tantalum and tungsten increase the lattice constant.

Such changes in the lattice parameters produce the result that silicon and vanadium increase the strengthening effectiveness of Ni_3Al through coherency hardening and iron, chromium, manganese, titanium, tantalum and tungsten increase the strengthening effectiveness of Ni_3Al through order hardening.

Of all these elements, iron, chromium, manganese are the most effective in assisting the hardening properties of Ni_3Al.

The invented Cu-Ni-Mn-Al alloys may have the composition given in Table 1.

Table 1

	% by weight
Nickel	19.0 - 26.0
Aluminium	1.9 - 3.2
Iron	0.5 - 1.5
Manganese	2.0 - 5.8
Chromium	0.3 - 1.5
Niobium	0.5 - 1.2
Titanium	0.0 - 0.5
Tungsten	0.0 - 0.5
Tantalum	0.0 - 0.5
Silicon	0.0 - 0.5
Vanadium	0.0 - 0.5
Copper	Remainder

An especially preferred alloy has the composition given in Table 2.

Table 2

	% by weight
Nickel	21.8
Aluminium	2.37
Iron	1.29
Manganese	3.88
Chromium	0.73
Niobium	0.82
Copper	Remainder

Preferably, alloys according to the invention have the following minimum properties after thermomechanical processing in the temperature range 800°C to 1000°C and heat treatment in the temperature range 350°C to 600°C.

0.2% Proof Stress	≥ 900 N/mm^2
Tensile Strength	≥ 1000 N/mm^2
Elongation ($5.65\sqrt{S_0}$)	≥ 10%
Hardness (HBN)	≥ 293 HBN

The invention will now be described in more detail with reference to the following examples.

EXAMPLE 1

Experimental melt compositions for Cu-Ni-Mn-Al alloys were prepared by conventional methods having the range of compositions given in Table 3 (all amounts being % by weight)

Table 3

Melt	Si	Mn	Al	Cr	Fe	Nb	Ni	Ti	Cu	Ni:Al
AA	0.02	5.40	1.96	0.46	0.95	0.75	23.42	-	Balance	11.94
AB	0.02	5.21	1.98	0.41	1.05	0.80	25.34	-	Balance	12.80
BA	0.03	4.12	2.29	0.49	1.21	0.76	21.23	-	Balance	9.27
BB	0.01	4.05	2.48	0.36	1.13	0.7	21.51	-	Balance	8.67
BC	0.02	4.14	3.07	0.44	1.14	0.66	21.4	-	Balance	6.97
BD	0.02	3.88	2.37	0.73	1.29	0.82	21.8	-	Balance	9.20
BE	0.03	4.14	2.52	0.42	1.2	0.72	23.7	-	Balance	9.40
BH	0.02	4	2.53	0.43	1.24	0.7	23.81	-	Balance	9.41
BM	0.01	4.11	2.84	0.32	1.18	0.65	25.84	-	Balance	9.10

The properties for each of the alloys from Table 3 following a production route to 2" diameter bar, involving thermomechanical processing in the temperature range 800°C to 1000°C are given in Table 4

Table 4

Melt	0.2% Proof Stress(N/mm²)	UTS (N/mm²)	Elong (%)
AA	788	1010	20.4
AB	803	1024	19.8
BA	840	1013	9.5
BB	819	1004	11.9
BC	880	1043	13.1
BD	902	1059	9
BE	820	1030	16.4
BH	805	1003	9.6
BM	810	992	9

In order to achieve higher strength properties, heat treatment to effect further precipitation hardening is carried out in the temperature range 350°C to 600°C. The results are given in Table 5

Table 5

Melt	0.2% Proof Stress (N/mm²)	UTS (N/mm²)	Elong (%)	BHN
BA	890	1052	13.5	282
BB	841	1034	14.3	293
BC	884	1065	15.5	285
BD	907	1074	10.4	311
BE	873	1075	9	311
BH	858	1047	12.1	285
BM	805	1024	10	277

Comparison of the properties of the various grades of Be-Cu alloys with Cu-Ni-Mn-Al with a nickel content of less than 20% and a Ni:Al ratio higher than 10, together with the AA and BD alloys is shown in Table 6

Table 6

Alloy Type	Be-Cu BMS 7-353 Minimum Properties	Cu-Ni-Mn-Al With Ni < 20% Ni:Al < 10	AA Ni = 23.4 Ni:Al = 11.9	BD Ni = 21.8 Ni:Al = 9.19	Be-Cu AMS 4650 Minimum Properties	Be-Cu AMS4535 Minimum Properties	Be-Cu AMS4651 Minimum Properties
0.2% Proof Stress (ksi)	621	720	788	907	966	931	1000
UTS (ksi)	828	890	1010	1074	1138	1159	1241
Elongation (%)	15	15.5	20.4	10.4	3	4	3
Hardness	259	269	277	311	335	323	340

The hardness of a material is a major contributor to its wear properties. Thus, the results indicate that, in order for Cu-Ni-Mn-Al to achieve wear properties comparable to Be-Cu, the hardness must be similar. The alloy BD which has the preferred composition of this invention, demonstrates a hardness of 311, showing that it would be expected to possess wear properties not dissimilar to Be-Cu.

As can be seen from Table 6, a significant improvement in both hardness and 0.2% Proof Stress for the alloy BD which has a nickel content >20% by weight and Ni:Al ratio <10 when compared to Cu-Ni-Mn-Al alloys with <20% nickel content and Ni:Al ratio >10.

In addition, the 0.2% proof stress and tensile strength of the preferred composition are comparable with that of Be-Cu to the specifications AMS 4650 and AMS 4535 while the elongation (ductility) is significantly improved.

The results indicate that the best properties are achieved with alloys having the general composition given in Table 7 and which possess a Ni:Al between 6.5 and 10.

Table 7

	% by weight
Nickel	21- 23
Aluminium	2 – 2.5
Iron	1 – 1.5
Manganese	2 – 4
Chromium	0.5- 1.2
Niobium	0.6 – 1.2
Titanium	0.0 – 0.5
Copper	Remainder

In the above tables, the following test procedures were employed

0.2% proof stress - BS EN 10002 Pt 1 2001
UTS - BS EN 10002 Pt 1 2001
Elongation - BS EN 10002 Pt 1 2001
Hardness - BS EN ISO 6506-1:1999

EXAMPLE 2

Experimental melt compositions for Cu-Ni-Mn-Al alloys were prepared by conventional methods having the range of compositions given in Table 8 (all amounts being % by weight)

Table 8

Melt	Si	Mn	Al	Cr	Fe	Nb	Ni	Ti	Cu	Ni:Al
CA	0.02	2.00	2.27	1.19	0.32	0.74	22.76	-	Balance	10.0
CB	0.02	3.00	2.36	1.21	0.32	0.71	23.00	-	Balance	9.7
CC	0.02	2.96	2.27	1.20	0.38	0.70	20.65	0.07	Balance	9.1
CD	0.02	3.07	2.45	1.41	0.48	1.20	22.10	-	Balance	9.0
CE	0.02	3.04	2.42	1.40	0.40	1.20	21.85	0.07	Balance	9.0

These alloys have a higher chromium content and a lower iron content than the alloys shown in Table 3. CD and CE also have a higher niobium content and CC and CE also include titanium. It is believed that these alloys may exhibit improved strength and/or hardness.

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